Energy, Mines and Resources Canada | Énergie, Mines et Ressources Canada

CANMET

Canada Centre for Mineral and Energy Technology | Centre canadien de la technologie des minéraux et de l'énergie

NOTCH TOUGHNESS OF THE HAZ OF PIPE AG SEAM WELD

J.T. MCGRATH
WELDING SECTION

FEBRUARY 1982

ENERGY RESEARCH PROGRAM

This document is an unedited interim report prepared primarily for discussion and internal reporting purposes. It does not represent a final expression of the opinion of the Canada Centre for Mineral and Energy Technology (CANMET)

Ce document est un rapport provisoire non-révisé et rédigé principalement pour fin de discussion et de documentation interne. Il ne représente nullement l'expression définitive de l'opinion du Centre canadien de la technologie des minéraux et de l'énergie (CANMET)

PHYSICAL METALLURGY RESEARCH LABORATORIES
REPORT ERP/PMRL 82-14(TR)

PHYSICAL METALLURGY RESEARCH LABORATORIES

REPORT ERP/PMRL 82-14(TR)

NOTCH TOUGHNESS OF THE HAZ OF PIPE AG SEAM WELD

by

J. T. McGrath

ABSTRACT

The instrumented impact test can measure the initiation of brittle fracture in the coarse grain heat affected zone, (CGHAZ), region. The onset of brittle fracture took place in the CGHAZ of the seam weld of pipe AG at a temperature of 28°C above that of the base metal.

INTRODUCTION

In the continuing study of arctic grade line pipe in the project "Evaluation of Materials for Natural Gas Pipelines", the notch toughness of the heat-affected zone of the mill seam weld is of particular interest for two reasons. This region has low toughness principally because of the coarse grain structure that develops through exposure to high peak temperatures (~ 1400°C) during submerged arc welding. Code bodies are attempting to define a suitable procedure for measuring the notch toughness of the CGHAZ (because of this low toughness). It is difficult to measure the energy and the load/displacement associated with fracture in the CGHAZ, because it is a narrow band, less than 2mm wide, and irregular in shape.

The present study evaluates the notch toughness of the CGHAZ in the seam weld of a grade 483 desulphurized line pipe. The pipe was designated pipe AG. The method used to measure notch toughness of the CGHAZ was the instrumented impact test.

Experimental Procedures

The composition of steel AG is listed in Table I. The seam weld of pipe AG was prepared by submerged arc welding with the spiral weld configuration. The toughness of the base metal and the CGHAZ of the seam weld were determined by the instrumented impact test.

Test specimens, machined from the pipe, had their long axis perpendicular to the rolling direction. All specimens were fatigue pre-cracked. Special measures were taken to ensure that the tip of the fatigue crack resided in the CGHAZ region for those specimens which were used to determine HAZ notch toughness. Complete details of test procedures for the instrumented impact test are provided in previous reports (1,2).

The microstructure of the base metal and the HAZ was assessed by optical microscopy.

RESULTS AND DISCUSSION

The load/time plots recorded in the instrumented impact tests allowed the calculation of the stress intensities, Ky, Km and K_f associated with the yield, maximum and fracture loads.

$$K = \frac{P.S}{B.W^{3/2}} \cdot \quad f(a/W) \qquad (1)$$

where P = load
B = specimen thickness
S = span
W = specimen depth
a = crack length

The values of stress intensity, recorded in Table 2, are plotted against test temperature for AG base metal (Fig. 1) and for the CGHAZ (Fig. 2). The temperature at fracture at the yield load, T_F, was used to define the level of notch toughness. The value of T_F for the CGHAZ was 28°C higher than that of the base metal. The fracture mode below the yield load was cleavage.

In terms of microstructure, the onset of brittle fracture is controlled by grain size and the type of transformation product. The fine ferrite

grains, of the AG base metal were responsible for the low yield load fracture temperature, T_F = -28°C. Steel AG had a low volume fraction of spherical sulphide inclusions i.e., V_f = 0.06% and a particle shape factor 0.97. These microstructural features are more beneficial in improving the resistance to ductile fracture.

Coarse, bainitic grains (prior austenite grain size ~ 100 μm) resulted in the higher value of T_F of the CGHAZ of the seam weld.

The fracture toughness of the CGHAZ of the seam weld of pipe AG was similar to that of pipe Z (2) and superior to that of pipe AE (3). Steels AG,Z and AE were desulphurized.

There was excellent correlation between the fracture surface features and the load/time plots in the fracture tests on the specimens containing CGHAZ. If the test temperature was such that brittle fracture was initiated in the CGHAZ, while ductile fracture took place in the base metal, the fracture surface showed cleavage facets in the HAZ and ductile tearing in the base metal [Fig. 3(a)]. Correspondingly, as shown in Fig. 3(b), the load/time plot exhibited a sharp drop as cleavage fracture was initiated in the CGHAZ. As the advancing brittle crack encountered the ductile base metal the load ceased to drop and rose slightly as normal ductile shear fracture ensued.

At low temperatures, where brittle fracture was initiated in the CGHAZ and continued through the base metal, cleavage facets were observed over the whole fracture surface [Fig. 3(c)]. In the load/time plot [Fig. 3(d)], the load dropped sharply at fracture initiation and did not recover as in Fig. 3(b).

At a temperature high enough for ductile fracture to occur in both the CGHAZ and the base metal, there were no differences in fracture characteristics between the two regions on the fracture face [Fig. 3(e)], and the fracture load gradually dropped after achieving maximum load [Fig. 3(f)].

CONCLUSIONS

1. The onset of brittle fracture took place in the CGHAZ of the seam weld of pipe AG at a temperature of 28°C above that of the base metal.

2. The instrumented impact test was capable of distinguishing the initiation of fracture in the CGHAZ. This was particularly evident when the mode of fracture was cleavage in the CGHAZ and shear in the base metal.

ACKNOWLEDGEMENTS

The author thanks Mr. R. Narraway for his technical assistance in all phases of the experimental program. He also thanks Mr. G. Weatherall for carrying out the instrumented impact tests.

REFERENCES

1. J.T. McGrath, M.J. Godden, J. Gordine and J.D. Boyd; Can. Met. Quart. 19, 99, 1980.

2. M.J. Godden and J.T. McGrath; Can. Met. Quart., 1981, in the press.

3. J.T. McGrath; Division Report ERP/PMRL 81-19 (TR), CANMET, Energy, Mines, and Resources Canada; 1981

TABLE 1. Composition of Steel AG

C	Mn	Si	S	P	Nb	Ni	Cr	Mo	La
0.08	1.70	0.15	0.004	0.014	0.072	0.20	0.09	0.21	0.0005

TABLE 2. Instrumented Impact Results

Specimen	T °C	a cm	K_Y MPa$\sqrt{m}$	K_M MPa$\sqrt{m}$	K_F MPa$\sqrt{m}$
Base Metal					
1	25	0.392	66.2	86.8	
2	25	0.377	70.1	95.2	
15	25	0.345	64.1	88.6	
14	0	0.360	63.6	89.0	
13	0	0.375	69.8	89.7	
11	-13	0.369	65.4	91.5	
12	-13	0.347	64.5	98.3	
3	-25	0.372			58.3
4	-25	0.387	68.6	85.7	
5	-25	0.331	61.9	70.7	
7	-50	0.327			52.0
9	-50	0.368			49.5
CGHAZ					
2	25	0.196	60.1	84.9	
12	25	0.372	65.7	85.4	
14	25	0.225	63.0		
16	25	0.343	57.7	85.0	
13	0	0.300			59.7
15	0	0.285			57.7
17	-13	0.336			62.6
3	-25	0.277			61.7
4	-25	0.283			52.1
5	-25	0.326	58.6		67.4
6	-50	0.305			55.0

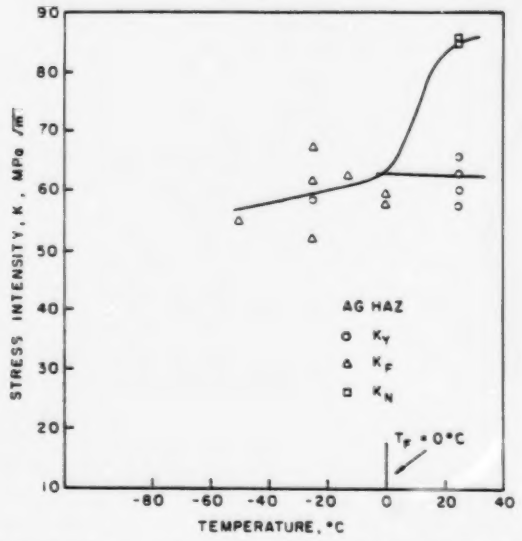


Fig. 1. Stress intensity versus temperature for AG base metal. (neg 6313)

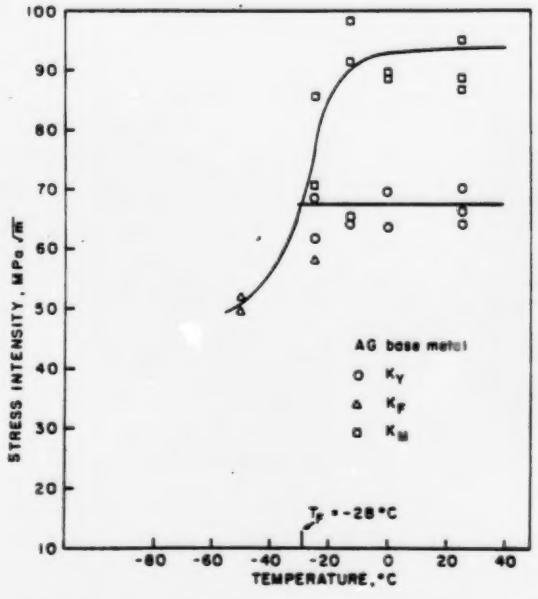
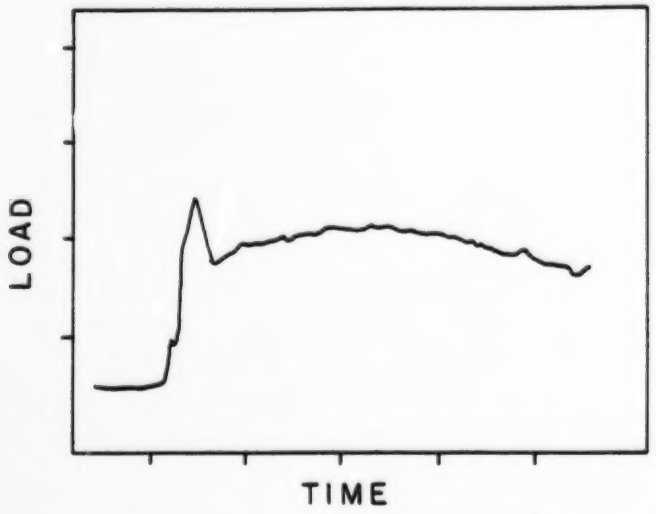
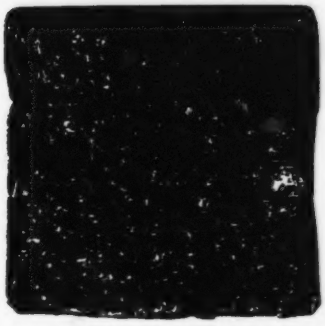


Fig. 2. Stress intensity versus temperature for AG HAZ. (neg 6568)

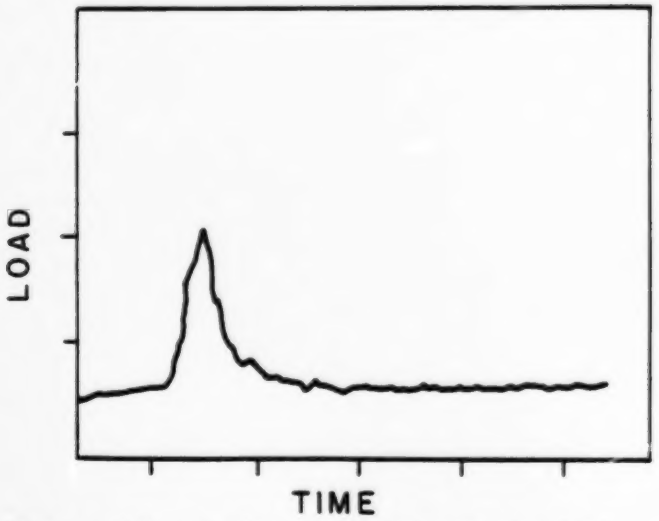
(a) Brittle fracture in the HAZ (region A) and ductile fracture in the base metal (region B). (neg 7176)



(b) Load time plot. Drop in load is associated with brittle fracture initiation in the CGHAZ. (neg 6317)

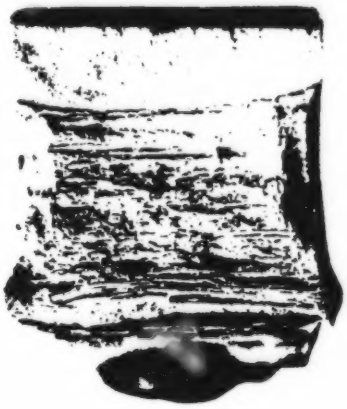


(c) Brittle fracture in the HAZ and base metal region. (neg 7175)

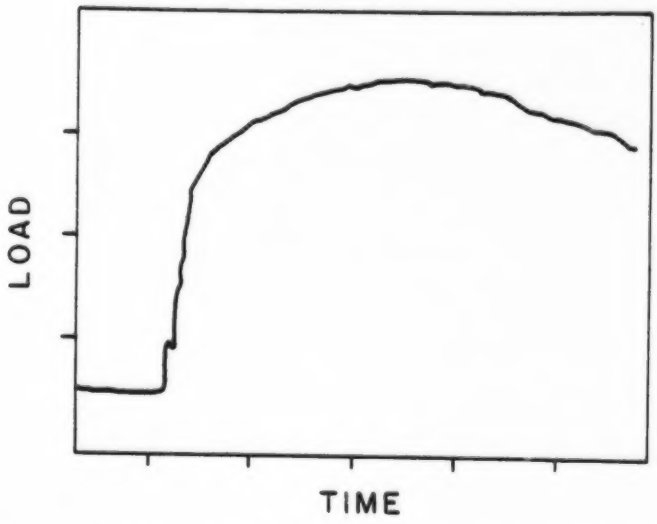


(d) Brittle fracture in the HAZ and base metal regions. (neg 7175)

Fig. 3. cont'd.



(e) Ductile fracture in the HAZ and base metal regions. (neg 7174)



(f) Load/time plot for ductile fracture in the HAZ and base metal regions. (neg 6319)

Fig. 3. Typical load/time traces with corresponding fracture appearance of instrumented charpy specimens.